Study of the Chemical & Physical Properties of Molding Sands

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A Study of the

Chemical, and Physical Properties

of

Molding Sands.

A thesis presented by

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to the

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of the

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for the degree

of

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of study in

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MOLDING SANDS.

The object of this discussion is to determine a specific method of grading molding sands. Up to date, we have no scientific method of grading such sands. The most common method now used for such work is to expose such sands to an examination by the head foundryman of each particular foundry, who by some unknown faculty is able, by continued handling, to tell whether a particular sand will answer the purposes which will be required of the sand in his line of work.

Authorities on the grading of molding sands vary quite widely on their conclusions regarding the grading of such sands. This is partly due to a confusion in terms, and partly due to the marked difference of opinion as to what constitutes a molding sand. It is not practical to give definite specifications for molding sands, on account of the great variety of work and the different methods of mixing sand for the same work.

COMPOSITION OF MOLDING SAND. Molding sand is made up of two distinct and necessary components; first, silica in the free state, and second, silicates of aluminium and iron. The free silica gives grain, refractoriness, porosity, and low shrinkage to the sand, while the silicate of aluminium furnishes bond. Free silica would be useless without the silicate of aluminium as it would not hold together. The silicate of aluminium would be worthless without free silica, as it would not have sufficient porosity and would have too great a shrinkage. The silica in the free state is nearly all, or should be quartz silica. In all molding sands found in nature, we have present several foreign substances which are undesirable, and are present from

necessity rather than from choice. Quartz silica mixed thoroughly with aluminium silicate, in proper proportions constitutes an ideal molding sand, if of the fineness desired.

INGREDIENTS OF MOLDING SAND. Quartz silica, silicate of aluminium, iron oxide, lime, and feldspar are the principle ingredients of molding sand. Quartz, or silicon dioxide, consists of approximately equal proportions of silicon and oxygen. It is white when pure but is, however, generally colored in molding sand by the presence of some iron oxide. Quartz, is the chief non-shrinkage element in molding sand. It has, however, no binding properties. The shape of its particles affects the strength of the sand, but they have no strength in themselves, as quartz is absolutely non-plastic. The size of the quartz particles determines the grade of the sand. The percentage best suited for a molding sand can only be determined by the kind of work for which it is to be used. The quartz silica should be kept as high as possible, on account of its heat resisting power, its tendency toward porosity and its low shrinkage.

The bond of a molding sand is aclay product. Clay consists of silicon dioxide, 46.4 percent; alumina, 39.7 percent; water, 13.9 percent. It is this 13.9 percent of combined water which gives the plastic properties to the clay. The bond of a molding sand is not pure clay, but is generally mixed with impurities, which weaken its binding power. clay is formed by the decomposition of feldspars. These are rocks containing silicate of aluminum together with the alkaline silicates. The clay acts as a binder for the sand and holds the refractory quartz silica together.

The purity and plasticity of the clay determine the amount necessary to give a sand its correct binding strength. The clay when pure is very refractory. The high percentage of clay in a sand destroys its porosity and causes high shrinkage and consequently cracking. A sand should be chosen with as low a clay content as is consistent with shop conditions. In foundries where a large percentage of old sand is used it is absolutely necessary to use a new sand containing a high percentage of bond. When a lower proportion of old sand is used, a new sand with less bond and consequently higher quartz silica will give a more porous facing.

Feldspars are silicates of alumina combined with silicates of the alkalies. These are generally present in small amounts in molding sands, but they should be kept as low as possible on account of their fusibility, as they tend to flux the rest of the sand and bind it together.

Oxide of iron is present in all molding sands, giving it its reddish color. It may be united with the bond as an impurity, or it may form a part of the quartz silica. The iron comes into the sand either from the original rocks from which the sand is formed, or from water containing iron which has trickled through the sand.

Lime and magnesia are always present in molding sand. They make the sand fusible and liable to crack and crumble in the mold. They may come from the water which has aided in the decomposition of the rocks during the formation of the sand.

ANALYSIS OF MOLDING SAND. The analysis of a good molding sand will give results within the following limits:

Substance	Percent
Silica	70 to 85
Alumina	5 to 10
Lime	0 to 3
Oxide of Iron	4 to 8.5
Magnesia	0 to 2

In a high grade molding sand used for heavy work the total percentage of iron oxide, lime and alkalies should not ordinarily exceed that of the molding sand used for lighter work.

POROSITY. Some sands are naturally porous, while others are very impervious to gas and moisture. The porosity of the sand determines the amount of venting necessary. Some sands must be vented very freely for all grades of work, while in others the use of a vent rod is hardly necessary. There are four factors which determine porosity: first, the proportion of quartz silica to the bond; second, the size of the quartz silica particles; third, the shape of the quartz silica particles; fourth, the condition of the bond. Generally speaking, the higher the proportion of the quartz silica the greater will be the porosity of the sand. The larger the quartz particles, the more porous will the sand be. It will be readily seen, however, that the size is limited, from the fact that the sand cannot be too coarse and still give a finish to the casting. The particle should therefore be kept as large as possible, and still produce the

desired effect as to finish. The porosity is also affected by the shape of the quartz silica particles. Irregular crystalline structures with sharp edges and corners will leave greater spaces between the particles than will regular shaped particles with smooth surfaces, which are apt to fit closely together and thus prevent a free passage of gas or air. The less the proportion of bond used, and still sufficient binding power in the sand, the greater will be the porosity. It is very necessary that a sand be chosen with a low percentage of strong bond rather than a large percentage of weak bond.

STRENGTH. The strength of a molding sand determine its adaptability for different kinds of work. Some castings may be made with sand having comparatively little strength, while for others a strong sand is absolutely necessary. The strength necessary is somewhat dependent on shop practice. The method of molding, running, venting, and mixing of the sand must all be considered in determining the proper strength of a sand for a given class of work. The practice of using flour, molasses or clay wash in mixing up facing, together with the proportion of coal dust and old sand used is also an important factor to be considered in the choice of a sand. A good mechanical mixer which intimately surrounds each particle of old sand with particles of new sand rather than putting the old and new sand together in chunks, also permits the use of a sharper sand. When flour or molasses is used or where the proportion of old sand to new sand is comparatively small the use of a sharp sand is possible.

The strength of a sand depends upon three conditions; first, the proportion of bond; second, the strength of bond; and third, the

shape of the quartz silica particles.

SIZE OF GRAIN. The grade of a molding sand is determined by its grain. Finer grain sands are used for lighter work. Sands are graded and sold by numbers, based upon the size of the grain. A sand should be as fine grained as possible and satisfactorily fill the other requirments of a molding sand. This is due to the fact that the finer grain will give a better surface to the casting. The fineness of the sand is obtained quantitatively by the use of a series of sieves. Of these, 80, 60, 40, 20, and 10 mesh are used. A sand whose particles are all small, but of uniform size will give better results than one with a combination of large and small grains.

In seeking specific conclusions on the grading of molding sand, I have attempted to choose a set of samples representing the most important molding sands on the market. With this fact in mind the following samples were chosen:

1. Sample received from Garden City Sand Company, Chicago, Ill, represents a "green" sand used for very heavy castings. This sand is mixed with Wanatau, Indiana, molding sand.

2. This sample is the first one, after being used for several castings.

3. Sample of Wanatau, Indiana, sand; partly burned, used for heavy castings.

4. This sample represents a Wanatau, Indiana, machine sand, this sand is "green".

5. This sample represents a "green" Albany sand, this sand is used

for light brass castings. Sample secured from foundry of Armour Institute of Technology.

6. This Sample is the above sample partly used. Sample secured from foundry of Armour Institute of Technology.

7. This sample represents a very heavy casting " green" sand; this sample secured from Butler Street Foundry, Chicago.

8. This sand is the above sand already used.

9. This sample is a Wanatau, Indiana, sand. Used for general casting. Sample secured from Butler Street Foundry, Chicago.

10. This sand is a mixed fine sand, ready for mold. Considered a good sand. Sample secured from Butler St. Foundry.

11. This sand is a brass casting sand, containing high percentage of loam. Sample secured from Garden City Sand Co., Chicago.

12. This sample represents a so-called Buffalo, or New Jersey Red sand; sample secured from Garden City Sand Company, Chicago.

The following method of analysis of molding sands was used:

(a) Physical. (b) Chemical. (c) Microscopical.

(a) 20 grams of the dried, unground sample were weighed within 0.01 gram, and stirred up with water; the loam being much lighter and finer than the sand, stays in suspension longer, and can be decanted off. By several decantations, and settlings, the loam and the sand will be separated. Very fine sand will settle as loam, and in some sands a great deal depends upon the judgement of the operator. Duplicates should check within 0.5%. After drying the loam, and sand, they were weighed separately to the nearest 0.01

gram and the result multiplied by five in orde to obtain the per-cent.

For the fineness, 100 grams of the dried, unground sample were taken and the portions rejected by a number 10, 20, 40, 60, and 80, sieve noted. The residue was also weighed, and the weights give the per-cent rejected by the respective sieves, direcly.

(b) A portion of the sample selected was dried at 100°C. and ground in an agate mortar; sample used must be capable of passing through 100 mesh sieve. On account of the large percent of silica present, 0.5 gram only was taken for analysis.

This was fused with sodium potassium carbonate in a platinum crucible, digested in an 8 inch evaporating dish, until the mass readily detached itself from the sides of the crucible; hydrochloric acid added to acid re-action, with care, to avoid spattering. When effervescence ceased, the crucible was removed, washed well, the solution evaporated over the water bath, baked at 110°C. until all odor of hydrochloric acid was gone. Residue was moistened with as little concentrated hydrochloric acid as possible, 20 c.c. of water added and brought to boil, then filtered by suction and washed with boiling water. The filtrate was evaporated to dryness to recover the soluble silica, baked at 110°C., moistened with hydrochloric acid and filtered on original filter. The whole of the silica being on the filter was washed with boiling water until the filtrate gave no evidence of chlorides when tested with a solution of silver nitrate. The substance in the crucible was moistened with concentrated sulphuric acid, hydrofluoric acid added, evaporated to dryness,

ignited, the loss being taken as silica.

The residue left was fused with sodium potassium carbonate, and the mass dissolved in dilute hydrochloric acid, and added to the first filtrate. To the combined filtrates, three grams of ammonium chloride was added and ammonium hydrate added to alkaline re-action; excess of ammonium hydrate boiled off. Aluminum and ferric hydroxides filtered off, washed well with hot water until free from chlorides, dried and ignited, weighed as oxides of iron and aluminum.

The filtrate from the aluminum and iron oxide precipitation was boiled with ammonium oxalate solution, filtered after standing an hour, washed with hot water, ignited to a constant weight and weighed as calcium oxide.

The filtrate from the calcium oxide precipitation was made alkaline with ammonium hydrate, and the magnesium precipitated with acid sodium phosphate, allowed to stand over night, filtered, washed with one or two c.c.'s ammonium hydrate, dried, ignited with care and weighed as magnesium pyrophosphate, the factor being 0.36243 to give magnesium oxide.

If a saturated solution of ammonium oxalate was used to precipitate the calcium, the ammonium salts will crystalize out when concentrating the bulk of the filtrate from the calcium precipitation prior to precipitating the magnesium. In order to get rid of these ammonium salts aquaregia is added and the solution evaporated to dryness, then heated for some time, until all the ammonium salts

have volatilized.

To determine ferric oxide, 1 gram of the dried, ground sample was weighed into a platinum crucible and silica volatilized with sulphuric and hydroflouric acids. The hydroflouric acid was evaporated off, and the residue fused with potassium acid sulphate. The fusion was dissolved in water, a small piece of platinized zinc added, and a few drops of sulphuric acid to affect reduction of the iron. When thoroughly reduced, the iron was titrated with a standard potassium permanganate solution.

Two grams of the dried, ground sample were weighed into a platinum crucible for loss on ignition, and subjected to the highest heat of an ordinary blast lamp with the aid of a clay ring. The sample was heated to constant weight, and the mass in the crucible closely examined.

(c) The sand obtained from the loam separated is carefully examined under the microscope, and the character of the grain noted; whether round, smooth, or sharp cornered, and the special peculiarities noted. The general appearance of the sample, color, consistency, fineness, and uses for which it is qualified are to be carefully noted. The following results were obtained by the above method of analysis:

Sample #1; A "green" sand used for very heavy casting. Secured from the Garden City Sand Co., Chicago, gave the following results:

Sand ---------- 57.8%

Loam ---------- 42.2%

Substance	Percent
Silica	60.8
Aluminum & Iron oxides	17.6
Calcium oxide	2.4
Magnesium oxide	2.37
Loss on Ignition	3.88

Separation of aluminum and iron oxides:

Iron oxide	8.61
Aluminum oxide	8.99

FINENESS.

Rejected by #10 sieve	28.75
" " by #20 "	22.52
" " by # 40 "	30.25
" " by #60 "	8.21
" " by #80 "	3.25
Residue	7.12

Under the microscope, this sample exhibited small, irregular shaped particles; mixture of quartz, mostly rounded, and small pieces of foreign material. Size of grain quite large.

Sample #2; This sample is the first one, after being used for several castings. Sample gave following results on analysis:

Sand	85.31%
Loam	14.69%

Substance	Percent
Silica	79.44
Aluminum & Iron oxides	13.00
Calcium oxide	1.00
Magnesium oxide	0.60
Loss on Ignition	4.32

Separation of aluminum and iron oxides:

Iron oxide	7.37
Aluminum oxide	4.63

FINENESS.

Rejected by #10 sieve	12.71
" " by #20	10.82
" " by #40	21.62
" " by # 60	26.52
" " by # 80	19.72
Residue	7.4

Under the microscope, this sample exhibited very small, irregular shaped particles of foreign material. Mix ed with larger peices of quartz of round shape. This sample showed very plainly manner in which the separate peices of sand attach themselves to one another. The irregular shaped particles seem to fit one another very perfectly.

Sample #3; Wanatua, Indiana, sand; partly burned, used for very heavy castings. Sample gave following results on analysis;

Sand ---------- 72.35 %

Loam ---------- 27.65 %

Substance	Percent
Silica	48.68
Aluminum & Iron oxides	10.68
Calcium oxide	3.00
Magnesium oxide	2.40
Loss on Ignition	2.11

Separation of aluminum and iron oxides:

Iron oxide	5.93
Aluminum oxide	4.75

FINENESS.

Rejected by #10 seive	14.03
" " by #20 "	32.13
" " by #40 "	25.31
" " by #60 "	16.28
" " by #80 "	6.31
Residue	6.51

Under the microscope, this sample exhibited rounded pieces of quartz mixed with smaller pieces of quartz. Sample appeared to be colored brown.

Sample #4; Wanatau, Indiana, machine sand. This sand is "green". Sample gave following results on analysis:

Sand ---------- 76.35%

Loam ---------- 23.65%

Substance	Percent
Silica	78.82
Aluminum & iron oxides	8.04
Calcium oxide	2.40
Magnesium oxide	1.58
Loss on Ignition	1.32

Separation of aluminum and iron oxides:

Iron oxide	5.57
Aluminum oxide	2.47

FINENESS.

Rejected by #10 seive	13.6
" " by #20 "	22.49
" " by #40 "	29.54
" " #60	19.04
" " #80	12.41
Residue	4.05

Under the microscope, this sample exhibited sharp cornered pieces of quartz mixed with a few smaller pieces of foreign material. Sample appeared to be a good grade of sand for light work.

Sample #5; Albany sand. This sand is "green" and is used for light brass castings. Sample gave following results on analysis:

Sand ---------- 34.85%

Loam ---------- 65.15%

Substance	Percent
Silica	84.26
Aluminum & iron oxides	11.20
Calcium oxide	3.40
Magnesium oxide	1.97
Loss on Ignition	1.29

Separation of aluminum and iron oxides:

Iron oxide	6.38
Aluminum oxide	4.82

FINENESS

Rejected by #10 sieve	23.02
" " by #20 "	22.15
" " by #40 "	15.23
" " by #60 "	18.53
" " by #80 "	15.42
Residue	7.96

Under the microscope, this sample exhibited very regular sized, sharp cornered pieces of quartz. Very small amount of foreign material present in this sample.

Sample #6; Albany sand. Sample already used. Sample gave following results on analysis:

Sand ---------- 66.35%

Loam ---------- 33.65%

Substance	Percent
Silica	77.08
Aluminum & iron oxides	16.34
Calcium oxide	2.8
Megnesium oxide	1.63
Loss on Ignition	1.91

Separation of aluminum and iron oxides:

Iron oxide	9.54
Aluminum oxide	7.10

FINENESS.

Rejected by #10 sieve	15.23
" " by #20 "	25.19
" " by #40 "	23.42
" " by #60 "	18.51
" " by #80 "	11.63
Residue	8.45

Under the microscope, this sample exhibited a mixture of sharp and rounded, large pieces of quartz and foreign material. This clearly shows the effect of usage on a good molding sand.

Sample # 7; Very heavy "green", casting sand. Sample gave following results on analysis :-

Sand ---------- 99.31%

Loam ---------- 0.69%

Substance	Percent
Silica	71.02
Aluminum & iron oxides	10.00
Calcium oxide	11.2
Magnesium oxide	3.51
Loss on Ignition	4.81

Separation of aluminum and iron oxides:

Iron oxide	5.33
Aluminum oxide	4.67

FINENESS.

Rejected by #10 sieve	25.55
" " by #20 "	17.25
Rejected by #40 "	24.20
" " by #60 "	12.85
" " by #80 "	20.63
Residue	4.39

Under the microscope, this sample exhibited a mixture of large pebbles of stone, with small, sharp cornered pieces of quartz, and rounded pieces of foreign material.

Sample #3; Very heavy "green" casting sand. Sample already used. Sample gave following results on analysis:-

Sand ---------- 96.64 %

Loam ---------- 3.36 %

Substance	Percent
Silica	74.12
Aluminum & iron oxides	18.00
Calcium Oxide	5.2
Magnesium Oxide	3.17
Loss on Ignition	4.67

Separation of aluminum and iron oxides:

Iron oxide	10.12
Aluminum oxide	7.88

FINENESS

Rejected by #10 sieve	17.8
" " by #20 sieve	13.6
" " by #40 "	30.2
Rejected by #60 "	16.57
Rejected by #80 "	15.59
Residue	3.59

Under the microscope this sample exhibited a mixture of large, sharp and somewhat rounded pieces of quartz and foreign material. Sample also showed presence of large pebbles of stone.

Sample #9; Wanatau, Indians, sand. Used for general casting. Sample gave following results on analysis:

Sand	95.61
Loam	4.39

Substance	Percents
Silica	80.5
Aluminum & iron oxides	11.52
Calcium oxide	3.4
Magnesium Oxide	2.62
Loss on Ignition	1.03

Separation of aluminum and iron oxides.

Iron oxide	6.69
Aluminum oxide	4.83

FINENESS.

Rejected by #10 sieve	1.98
Rejected by #20 sieve	4.20
Rejected by #40 sieve	19.55
Rejected by #60 sieve	30.89
Rejected by #80 sieve	22.48
Residue	16.02

Under the microscope, this sample exhibited nice, large, sharp cornered pieces of quartz. Particles of uniform size.

Sample #10; A mixed fine sand ready for molding. Used for general casting. Sample gave following results on analysis:

Sand ---------- 89.2 %

Loam ---------- 10. 8%

Substance	Percent
Silica	77.96
Aluminum & iron oxides	18.04
Calcium oxide	3.00
Magnesium oxide	1.12
Loss on Ignition	0.96

Separation of aluminum and ironoxides:

Iron oxide	10.15
Aluminum oxide	7.89

FINENESS

Rejected by #10 sieve	2.43
Rejected by #20 sieve	8.36
Rejected by #40 sieve	22.7
Rejected by #60 sieve	23.72
Rejected by # 80 sieve	23.85
Residue	15.57

Under the microscope, this sample exhibited sharp cornered pieces of quartz mixed with smaller pieces of quartz.

Sample #11; Brass casting sand containing high percentage of loam. Sample have following results on analysis:

Sand ---------- 11.55%

Loam ---------- 89.45%

Substance	Percent
Silica	74.38
Aluminum & iron oxides	13.6
Calcium oxide	1.60
Magnesium oxide	2.11
Loss on Ignition	2.30

Separation of aluminum and iron oxides:

Iron oxide	6.74
Aluminum oxide	6.86

FINENESS

Rejected by #10 sieve	0.00
Rejected by #20	23.95
Rejected by # 40 "	22.53
Rejected by #60 "	5.07
Rejected by #80 "	12.18
Residue	35.94

Under the microscope, this sample exhibited large pieces of sharp cornered quartz mixed with smaller pieces of quartz and foreign material.

Sample #12; Buffalo or New Jersey Red molding sand. Sample ave following results on analysis:-

Sand ---------- 88.6 %

Loam ---------- 11.4%

Substances	Percent
Silica	85.9
Aluminum & iron oxides	10.00
Calcium	2.00
Magnesium oxide	1.66
Loss on Ignition	1.18

Separation of aluminum and iron oxides:

Iron oxide	5.18
Aluminum oxide	4.82

FINENESS

Rejected by #10 sieve	19.3
Rejected by # 20 sieve	30.1
rejected by # 40 sieve	35.67
rejected by #60 sieve	5.64
Rejected by #80 sieve	2.2
Residue	2.3

Under the microscope, this sample exhibited large pieces of sharp cornered quartz . Quartz colored brown.

The life of different sands is variable. Sands are known to have "lived" for fifteen years. No sand is "dead". Sands are used continuously by mixing with small amounts of new sand. All new sands are mixed with burned sand before use.

The loss on ignition should not be too high in any sand. This loss should be just great enough to furnish the amount of carbon dioxide necessary to convert the calcium and magnesium oxides present in the sand into calcium and magnesium carbonates. If the loss on ignition is greater than this amount, the excess represents organic matter, and thereby lessens the "life" of the sand, thus making it a poor sand.

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I conclude from my results, that a molding sand can be very intelligently classed or graded after a chemical analysis and a fineness test.

The chemical analysis would tell me from the percentage of silica, and loam present whether the sand was a good or a poor sand I would class iron oxide, calcium oxide and magnesium oxide as harmless impurities which would improve a sand considerably by their absence.

The fineness test would readily tell me, after the chemical analysis has done all it is capable of, whether the sand could be used for heavy or light work.

I should say that a good molding sand must have the following rational analysis:

Loam ---------- 20 - 40%

Sand ---------- 65 - 85%

I find also that after a sand has been used for a few times its silica contents decreases, its iron oxide content increases, its calcium oxide and magnesium oxide content remain about the same, and loss on ignition increases slightly. The sand also becomes coarser after use. The increase in iron oxide is due to the adhering of small particles of iron to the sharp grains of sand during pouring of metal. I see no reason why the silica content should vary in the same sand before and after use. I conclude from this that a sand is considerably poorer for molding purposes after use than before, and am of the belief that the sand can be made " well" after use by mixing with "green" sand of the same grade.

With the above facts in mind, I would grade the twelve sands analyzed in the following manner:

#1. Good sand owing to high percent of loam. Silica content not as high as might be. From Fineness test, I should say the sand could be used for small and medium weight castings.

#3. I would grade this sand as poor sand. As long as this sand holds together on pounding, I think it will answer the purpose it is put to, namely very heavy casting as in this work, a very good sand is not necessary.

#4. I would grade this sand as a good molding sand for light work. Has a good percentage of loam and silica while the iron oxide calcium oxide, magnesium oxide and loss on ignition are comparatively low.

#5. I would grade this sand as a very good sand. The percentage of loam is rather high while the silica content is very good. Impurities in this sand are low.

#6. This analysis brings out the effect of usage on a sand, very clearly. It will be noticed that the silica content has decreased, iron oxide content has increased while the impurities remain about the same.

#7. I would hardly class this sand as a molding sand from its rational analysis, as there is practically no loam present. All that is necessary to make this sand a fair sand for its use (heavy castings) is the addition of some clayey substance, to increase the loam content.

#8. This sand would be graded as a good heavy casting sand. The fineness test shows that it could not be used for light casting

with good results.

#9. I would grade this sand as a good sand for general foundry work, the loam content might be higher.

#10. I would grade this sand as a very good foundry sand. The chemical analysis shows that the sand has the proper composition. The fineness test shows that the sand is neither very coarse or very fine.

#11. I would grade this sand as an excellent light casting sand. The percentage of loam is rather high but in special cases this could be deceased by the addition of silica or plain sand.

#12. I would grade this sand as a very good general foundry sand. Has a good percentage of loam and silica and approaches the analysis of Albany sand which is considered a standard molding sand by many authorities.

In concluding, I would say that if a good mechanical mixer is obtainable, I firmly believe ideal molding sands can be manufactured from pure quartz and clay according to desired proportions. I think that the day of made-to-order molding sands is not far away, as it is a well known fact that the present sources of molding sands are rapidly being exhausted and somebody will soon be called upon to meet the ever increasing demand for this kind of sand.